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The Citrus Thrips, Measures For Its Control, and Their Effect on Other Citrus Pests

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SUMMARY

The citrus thrips is prevalent in most citrus regions in California and Arizona, where it is the cause of serious losses annually. It attacks all varieties of citrus but is of greatest economic importance on navel oranges and lemons. The damage consists chiefly of the impaired appearance and salability of the fruit and the stunting of the foliage.

The eggs are deposited in tender fruits and foliage. The overwintering eggs usually begin to hatch early in March.

The citrus thrips probably has 10 to 12 generations annually in localities having the higher temperatures. It is the second generation, developing chiefly during May and the early part of June, that causes the most damage to orange fruits, but lemons are attacked throughout the active growing season.

For a number of years three or four applications per year of lime-sulfur, alone or with nicotine, was the recommended treatment for the citrus thrips. In 1927 sulfur dusting largely replaced spraying and reduced the annual cost considerably.

In 1939 tartar emetic was found by the California Agricultural Experiment Station to be extremely effective against the citrus thrips and relatively safe under all conditions. Since then it has largely supplanted sulfur in the control of the thrips. In 1942 the citrus thrips was found to have developed tolerance to tartar emetic in certain localities in southern and central California.

The period during which oranges are injured is while they are growing from pea size to walnut size, and the greatest protection is obtained by any treatment if it is applied at the beginning of this period. *Timing is vital when reliance is placed on a single treatment, applied preferably as the oranges approach pea size.* One spraying with tartar emetic or lime-sulfur at this time, or three dustings with

sulfur during the period of damage, have usually afforded commercial protection to oranges.

The period of chief injury to lemons by thrips usually is from June 1 to October 15. For optimum protection, lemons should be sprayed with tartar emetic three times during this period (in non-resistant areas), or dusted five times with sulfur.

Where the citricola scale or the black scale occurs with the thrips, sulfur dusting reduces the populations of these insects by killing many small scales.

The populations of the citrus red mite are reduced by sulfur applications if temperatures are sufficiently high to activate the sulfur.

Splitting and *Alternaria* diseases of oranges are materially reduced by applications of lime-sulfur spray or sulfur dust.

Adequate measures should be taken to protect the operators from any poisonous or irritating materials used for the control of the citrus thrips.

INTRODUCTION

The citrus thrips (*Scirtothrips citri* (Moult.)) is one of the major pests of citrus, especially navel oranges and lemons, in California, and of oranges and grapefruit in Arizona. It causes scarring and stunting or dropping of the fruit, and interferes with foliage development. This pest occurs in California, from the upper Sacramento Valley to the Mexican border, and in the Yuma and Salt River Valleys of Arizona.

The most severe and consistent damage to oranges occurs in Tulare, Fresno, and Kern Counties, in central California. In southern California damage to oranges varies greatly from year to year and differs widely between localities. The most serious injury is in groves in the hotter interior valleys, especially in the Redlands, Rialto, Etiwanda, and San Fernando districts. Oranges in the sandy-soil section of the Redlands area are seriously damaged in most years. The citrus thrips is found to be increasingly scarce as one passes from the interior to the coast. In Arizona it is chiefly a pest of navel oranges in the Salt River Valley and of grapefruit near Yuma. In most California districts grapefruit is not subject to serious injury.

The results of observations and experiments pertaining to the citrus thrips on the Pacific coast, supplemented by information on control measures obtained from a review of the literature, are discussed in this paper, which is intended to make readily available to citrus growers a knowledge of the insect and the measures for its control.

NATURE OF INJURY

The damage caused by the citrus thrips consists chiefly of the unsightly scarring of the fruits and the checking of foliage development. Damaged oranges on an average are smaller at maturity, and the evidence indicates that a certain percentage of young fruits drop when severely attacked by thrips. In feeding, the needlelike mouth parts of the insect are forced into the plant tissue and the plant juices are sucked up through the feeding cone. The repeated feeding punctures finally cause a scabby, scurfy appearance of the attacked fruits (fig. 1). Feeding liberates minute quantities of oil from the rind which, under certain conditions, add to the disfiguration. Usually

a characteristic ring develops around the stem end of a scarred fruit.

Oranges are most susceptible to severe injury by thrips when between the size of a pea and that of a small olive. Injury at this time may result in grooved or malformed fruits. Upon reaching the size of a walnut, the toughening skin is more resistant, and oranges this size or larger are less severely injured.

In feeding on the foliage the thrips attack tender leaves, succulent stems, and opening buds. At times the tree buds offer the only suitable food and may be entirely checked in growth, with dense clusters of dead buds resulting. Heavily attacked leaves become misshapen, thickened, and stunted (fig. 2).

In the districts where thrips attacks are more severe the injury to foliage at times checks the growth of the trees and restricts the for-



FIGURE 1.—Injury to navel oranges caused by the feeding of the citrus thrips.

mation of fruiting wood. This may cause an economic loss even greater than that from the injury to the fruit.

The injury to lemon fruits and foliage is similar to that of oranges. It consists of the scarification of the rind of the young lemons and similar disfiguration of the foliage. The Eureka variety is especially susceptible to the citrus thrips.

ECONOMIC IMPORTANCE

From 1925 to 1932, inclusive, examination of hundreds of thousands of navel oranges in untreated orchards and plots in central California indicated an average reduction in grade of 47 percent. This means that during an average year the equivalent of 1,138,500 packed boxes of fruit would be damaged by thrips in Tulare County alone if no protective measures were taken. Under average market conditions this loss would amount to nearly \$1,000,000. The actual average annual loss is reduced by control measures to about \$350,000 in that area.



FIGURE 2.—Tender orange twigs with leaves rolled and distorted by the feeding of the citrus thrips.

The average annual cost of thrips control in Tulare County during the above period was from \$140,000 to \$150,000. The average damage to the fruit, together with the cost of control, amounted to nearly \$500,000 annually in this one county.

SEASONAL HISTORY, HABITS, AND APPEARANCE

The citrus thrips overwinters in the form of tiny, bean-shaped eggs, deposited during the autumn in the tissues of tender leaves and stems (fig. 3). The average date of first hatching has been March 2 in central California and March 5 in southern California. When first hatched (fig. 4), the thrips are very pale, nearly colorless, with bright-red eyes. As they grow they turn yellowish and then orange amber, the eyes become dull red, and the abdomen widens noticeably (fig. 5). When fully grown the larva seeks concealment in order to pupate, or transform to the adult stage. Most of the larvae drop to the ground for this purpose, and find their way into fallen, curled leaves. More than 2,000 mature larvae dropped in one night under one tree.

The adult thrips has wings, is pale orange yellow, and is 0.02 to 0.04 inch in length (fig. 6). It is very restless, and can fly short dis-

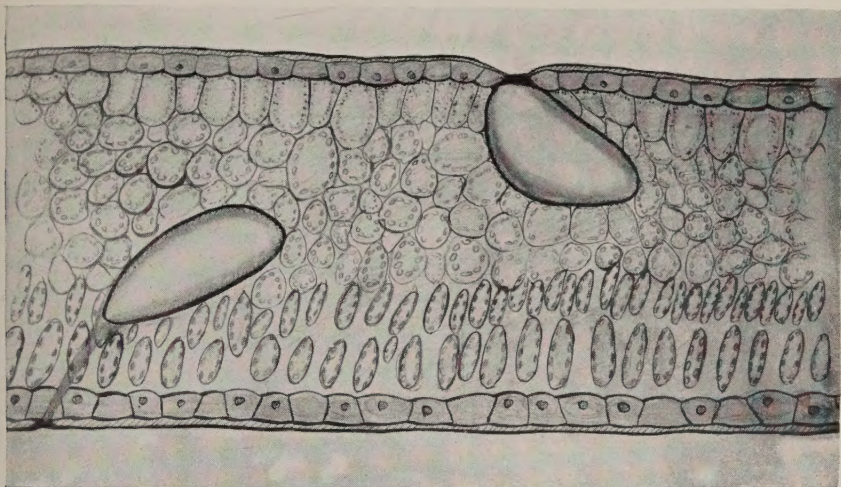


FIGURE 3.—Transverse section (semidiagrammatic) of orange leaf, showing position of eggs of the citrus thrips in the leaf tissue.

tances. Females can reproduce without mating, but in such instances produce only male progeny. The first-generation thrips feed on and often damage tender spring foliage.

The development of the insect from egg to adult requires about a month in cool weather, but may be completed in hot weather in 13 to 17 days. There are probably from 10 to 12 generations a year in the warmer localities.

The first generation is usually rather well defined, but succeeding generations overlap. The second-generation thrips develop chiefly during May and the early part of June. When the young oranges first form (May 5, average date in central California; May 8, average in southern California) the thrips of this generation leave the toughening foliage and begin to attack the tender fruits. Some of the eggs are laid in young fruit, as soon as it begins to form. The average date of the earliest thrips injury to new oranges observed in central California was May 11 and in southern California May 18. The later generations cause less damage to oranges, but frequently cause con-

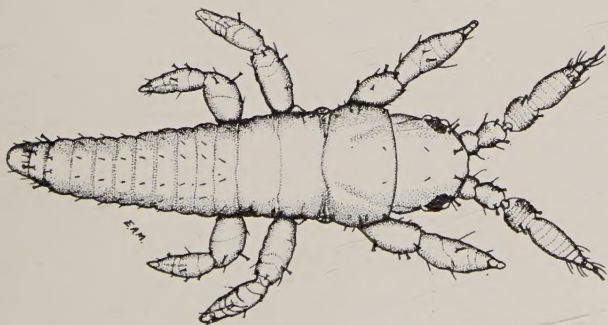


FIGURE 4.—Newly hatched larva of the citrus thrips. $\times 258$.

siderable damage to lemons, which continue to form throughout the summer.

During weather with temperatures above 105° F. there is a tendency toward lower thrips populations; for instance, in the Imperial Valley the citrus thrips is relatively scarce. Usually during October the thrips population again undergoes a marked reduction. Living thrips are rarely found in central California after December 1. During mild winters in southern California a very few individuals may survive the winter.

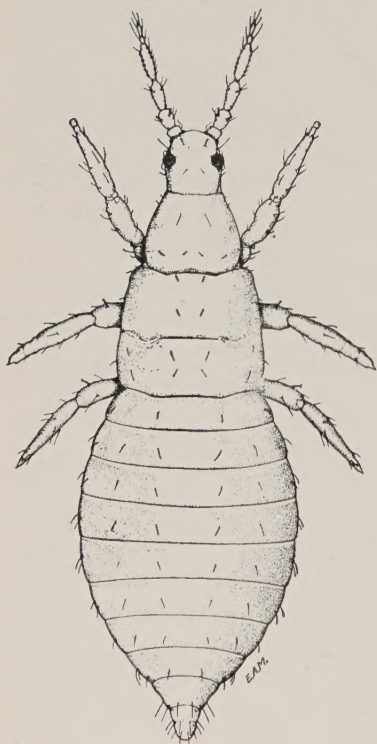


FIGURE 5.—Well-developed second-instar citrus thrips. $\times 117$.

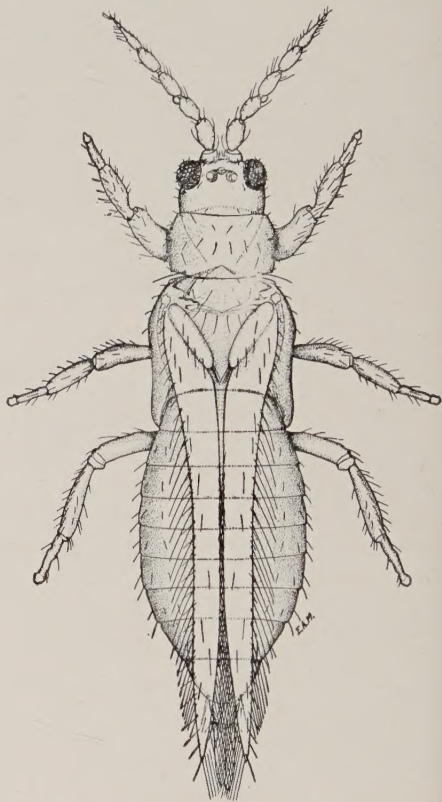


FIGURE 6.—Adult female of the citrus thrips. $\times 95$.

Although citrus thrips straggle at times to noncitrus plants, having been recorded on 30 other hosts, citrus trees remain the chief feeding ground throughout the year. The peppertree (*Schinus molle* L.) is the only other host on which the citrus thrips is known to overwinter in the egg stage.

NATURAL ENEMIES

Four or five species of predaceous insects and spiders are known to attack the citrus thrips, but they exert little control on the thrips population.

CONTROL OF THE CITRUS THRIPS

HISTORICAL

The earliest work on control of the citrus thrips was conducted about 1910 by Jones and Horton (6),¹ who referred to it as the "orange thrips." For a number of subsequent years three or four sprayings annually with lime-sulfur alone, or with nicotine, was the recommended program for the control of the citrus thrips (5). The first work with sulfur dusts was done in 1926, and by the following year the value of this material had been demonstrated (7). A variety of dosages and schedules were tested, and by 1936 the sulfur-dusting programs on oranges had been adapted successively to the requirements of central California, southern California, and Arizona. As a result, the annual cost of thrips control had dropped considerably, and sulfur dust was in general use.

In 1939 Boyce and Persing (1), of the California Agricultural Experiment Station at Riverside, published a report on promising results obtained in preliminary tests with tartar emetic against the citrus thrips. This material had been successfully used earlier in the East for the control of the gladiolus thrips by H. H. Richardson (17) and by R. H. Nelson (13). Later, in orchard tests, Persing, Boyce, and McCarty (15) found that a tartar emetic-sugar spray gave more complete control of the citrus thrips than any other known material. Control by this spray is somewhat cheaper than by the sulfur-dusting method, gave uniformly excellent results, and soon largely replaced dusting except where it was desirable to combat the citricola scale or the black scale at the same time.

In 1942 Boyce, Persing, and Barnhart (3) reported that the citrus thrips in certain lemon and orange orchards in southern California (San Fernando Valley) and in central California appeared to have developed high tolerance for tartar emetic. This has been confirmed by the writer by field observation and by laboratory tests where percentages of survival of thrips known to have eaten the poison were very high.

Precautions in Using Insecticides

Many of the chemicals used for insect control are poisonous to man, or irritating to the respiratory tract. Persons unskilled in handling these substances should secure the advice or supervision of experts before attempting their use.

THRIPS CONTROL ON ORANGES

The application of measures to protect orange fruits is limited to the early growing period up to the time when they are about the size of a walnut, or from about May 1 to about June 20. To afford maximum protection throughout this period the treatment must be accurately timed, especially when a single treatment is relied upon for preventing fruit injury, as is the case with certain sprays. Experience has shown that the greatest benefit from a single treatment results if it is applied when most of the petals have been shed and many of the oranges are approaching the size of a pea. This date varies from year to year, but in central California it has averaged about May 5 and in southern California about May 8. An applica-

¹ Italic numbers in parentheses refer to Literature Cited, p. 12.



FIGURE 7.—High-capacity power duster developed by California growers for treating citrus orchards. (Note that dust is penetrating to the second row of trees.) When poisonous dusts are used, or when sulfur dust is applied under conditions that result in irritation to the respiratory tract, an approved type of dust respirator should be worn by the operator. The eyes should be protected by the use of goggles when necessary. In order to reduce the fire hazard when applying sulfur dust, the dust rig should be equipped with a drag chain to carry off static electricity.

tion is often desirable in August or September to protect the cycle of foliage developing at that time.

SULFUR DUST

Where sulfur dust is used on oranges (fig. 7), three applications are recommended, as follows: (1) Before the first-brood larvae pupate (March 20 to 31); (2) when three-fourths of the petals have fallen from the trees (April 20 to May 15); and (3) about 3 weeks after the second dusting (May 15 to June 10). In the first application about 100 pounds per acre should be used, in the second about 75, and in the third about 50. Except where rains interfere or the application has been faulty this dusting schedule should give satisfactory protection to oranges against thrips damage. If a fourth dusting should be deemed necessary, the timing will depend on when rain falls or when the thrips population becomes threatening. In the case of adverse weather conditions the dusting program is more reliable than a single spray, because even if one dust application is interfered with, the others are likely to give considerable control.

TARTAR EMETIC-SUGAR SPRAY ON ORANGES

The recommendations issued by the California Agricultural Experiment Station for control of thrips on oranges are as follows: If a spray duster is used, $1\frac{1}{2}$ pounds of tartar emetic and $1\frac{1}{2}$ pounds of sugar in 20 to 50 gallons of water should be applied per acre. When tartar emetic-sugar is applied with broom guns or boom sprayers, 2 pounds each of these materials should be applied in 100 to 200 gallons of water per acre. It was found by Persing and Boyce (14), of the

California Agricultural Experiment Station, that smaller quantities of tartar emetic and sugar could be used effectively when applied with the spray dusters,² which release the spray at 60 pounds' pressure into a strong blast of air. The liquid reaches the tree in a rather fine mist and only the outer shell of the tree needs to be treated. It was found that driving speeds of from 2 to 5 miles per hour were satisfactory, provided the correct quantity of material was applied per acre.

Except where resistance has developed, the tartar emetic-sugar program is fully as effective against the citrus thrips as the sulfur-dust program and is somewhat cheaper. No injury of importance to citrus fruit or foliage by tartar emetic has been recorded, whereas there is some danger of injury to the fruit from sulfur dust if it is applied during periods of high temperatures, and if the applications are too frequent. The tartar emetic-sugar spray may be applied in the daytime under conditions of greater air movement than is desirable for the sulfur dust, which is preferably applied at night when the air is still. Tartar emetic is, however, ineffective against certain other citrus pests in the control of which sulfur is of considerable value.

THRIPS CONTROL ON LEMONS

Growth conditions in lemon orchards differ widely from those in orange groves. Lemons blossom and set fruit throughout the entire year, instead of during one brief period, as do oranges; and small, tender lemons and tender foliage are usually present throughout the period of thrips activity. Most of the injury occurs from June to the middle of October. In southern California, where most of the lemon acreage is situated, lemon fruits and foliage suffer little damage from thrips prior to June. The application of control measures to lemons before the latter part of May is therefore of limited value.

TARTAR EMETIC-SUGAR SPRAY ON LEMONS

The California Agricultural Experiment Station recommends two applications of tartar emetic and sugar on lemons, the first late in May and the second in August. The writer has obtained better control of thrips on lemons with three treatments of these materials applied in mid-May, early in July, and early in September than with two treatments applied in May and early in September. In most years the highest level of thrips population on lemons has been reached between August 15 and September 15, and this strongly indicates the need of an application during this period. However, owing to differences in condition of fruit and foliage and to variation in the thrips population between orchards and between seasonal periods, the matter of defining a rigid time schedule of treatments on lemons is impracticable. The tartar emetic and sugar should be applied at times when thrips populations are threatening to damage the cycles of tender fruit and foliage. On lemons the recommended formula is 3 pounds of tartar emetic and 3 pounds of sugar in 20 to 50 gallons of water per acre, applied with the spray duster. When applied with broom guns or boom sprayers, 4 pounds each of tartar emetic and sugar in 100 to 200 gallons of water should be used per acre.

² The term "spray-duster" has been applied to rigs consisting of powerful dusting machines equipped also with tanks for liquid sprays. A series of nozzles is installed along the outlet of the blower, so that the spray is blended with the air blast, and is carried to the trees in the form of a fine mist. These rigs may be used to apply dry dusts, or liquid sprays, or a combination of both.

Boyce and Persing (2) found that a spray containing nicotine and sugar is promising as an alternative for tartar emetic and sugar in areas with resistant thrips. The recommended formula is nicotine sulfate 1 quart and sugar 8 pounds per 100 gallons when applied with spray dusters at 1 gallon per tree.

In studies recently conducted by the author (11) (12), certain other compounds have been found to be very toxic to the citrus thrips. Prominent among these are DDT (2, 2-bis (parachlorophenyl)-1, 1, 1-trichloroethane) and anabasine. Further work is needed before these materials, neither of which is yet available to growers, can be recommended for use to control the citrus thrips.

SULFUR DUST ON LEMONS

Prior to the discovery of the effectiveness of tartar emetic in the control of the citrus thrips, sulfur dust was widely used for this purpose on lemons. Extensive experiments have shown that satisfactory protection of lemon fruits and foliage can be provided by a proper dusting schedule. As previously mentioned, it is hardly possible to outline a rigid schedule of treatment for thrips on lemons. Where sulfur is used, four or five applications are usually necessary to give satisfactory protection. The available information indicates that a satisfactory schedule includes five applications at 4-week intervals, beginning about May 25. In the first application 100 pounds of material should be used per acre; in the second, 75 pounds; and in subsequent applications, 50 pounds. In comparative tests the schedule of five sulfur dustings has given protection to lemon fruits and foliage fully equal to that from two sprayings with tartar emetic but a little poorer than that from three applications of tartar emetic.

The objection to the use of sulfur on lemons has been the hazard of fruit burn in hot weather. When daily maximum temperatures reach 100° F. or higher, soon after dusting, the fruit has at times been damaged. In most cases part of the loss assessed to sulfur burn actually was sunburn and many of the lemons injured by sulfur would have been sunburned without it. In most of the cases investigated less than 1 percent of all lemons were damaged by sulfur. The greatest recorded loss caused by sulfur burn in the experimental orchards was about 4 percent of the fruits that were on the trees at the time.

EFFECT OF THRIPS-CONTROL METHODS ON OTHER CITRUS PESTS

CITRICOLA SCALE

In districts where the citricola scale (*Coccus pseudomagnoliarum* (Kuw.)) is present, in addition to the citrus thrips, the two pests usually have been combated jointly. This is especially true in central California and in the Redlands-Riverside-Arlington area in southern California. Either lime-sulfur spray or the sulfur dust program has commonly kept these two insects under control at the same time (8).

In the hotter inland districts, where temperatures are high enough to activate the sulfur dust, light to moderate infestations of the citricola scale usually can be controlled, along with the thrips, by the sulfur-dusting method. Where the scale population is moderate, one additional dusting, applied 2 or 3 weeks after the third, is often advisable.

The period of hatching of the citricola scale usually is between May 1 and July 10. The crawlers are the stage most easily killed, and in order to get the best possible control the foliage should be kept coated with sulfur dust during this period.

Where the citricola scale is rather abundant, it is good economy to clean up the orchard by proper spraying or fumigating. Once clean, many orchards may be kept in satisfactory condition over a period of years by the regular sulfur-dusting program.

Where a single application of lime-sulfur is to be relied upon for control of both the thrips and the citricola scale, the greatest effectiveness is obtained when the lime-sulfur is applied at a strength of 2 percent when the oranges are nearing the size of a pea, which will usually be between April 25 and May 10. The spray should be applied thoroughly to both the inside and the outside of the tree. To avoid injury, growers should not spray with lime-sulfur when temperatures are likely to reach or exceed 100° F.

BLACK SCALE

Against the black scale (*Saissetia oleae* (Bern.)) also, the greatest effectiveness of sulfur is exerted during the period when the eggs are hatching and the crawlers are attempting to settle. The first dusting should be done at the earliest observance of hatching and, to get the greatest benefit, dustings should be continued at intervals of 3 or 4 weeks until from two-thirds to nine-tenths of the scales have hatched.

In all tests made by the writer, sulfur applications have caused marked reductions in the populations of young black scales. At Redlands and at Piru this mortality from sulfur alone gave commercial control in a number of cases and partial control in others. When applied as a supplement to fumigation, sulfur dusts have added materially to the mortality (10).

CITRUS RED MITE

Early workers called attention to the effectiveness of sulfur against the citrus red mite (*Paratetranychus citri* (McG.)) also known as the red spider. Quayle (16) stated that it was "one of the most satisfactory remedies." He cautioned that proper control from sulfur depended on temperatures high enough to activate it. In recent years growers have relied chiefly on oil sprays and nitrated phenol dusts for control of the citrus red mite. In the tests with sulfur against thrips and scale insects, marked reductions of the red spider population often have been observed.

SPLITTING AND ALTERNARIA

Studies by H. S. Fawcett, of the California Experiment Station, in cooperation with the present author, showed definitely that either the sulfur dust or the lime-sulfur spray causes marked reductions in splitting and *Alternaria* diseases of navel oranges (4). During certain years these diseases cause considerable losses.

SULFUR SPECIFICATIONS

In dusting citrus trees for the control of the citrus thrips and scales, maximum results can be obtained only by using well-prepared sulfur dusts. Sulfur dusts should be: (1) *Pure* (95 to 98 percent); (2) *fine*, (at least 95 percent by weight goes through a 325-mesh screen); (3)

free applying (because of the addition of a small quantity of conditioner, such as magnesium oxide or magnesium carbonate).

Experiments made by the writer have shown that within certain limits there is a positive correlation between the fineness of sulfur and its effectiveness against the citrus thrips (9) in that greater effectiveness resulted from increased fineness. However, certain sulfurs of extreme microscopic fineness sublime so rapidly that the toxic action is spent too soon. The loss in grade of fruit through the use of inferior, coarse sulfurs usually outweighs the small saving in the initial cost of material.

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